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SUBJECT: Objectives in the Exploration of the Solar System - Case 103-2

DATE: March 9, 1967

FROM: F.G. Allen

ABSTRACT

A summary is given of some of the most important scientific questions currently being asked about the solar system. These should serve as a set of goals against which proposed planetary space missions may be evaluated.

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MEMORANDUM FOR FILE

In the past few years we have sent unmanned probes close to Venus and Mars, we have soft-landed on and photographed the Moon, and we have sent probes far out around the sun. In the years ahead, we will surely accelerate this exploration of the bodies and space in our solar system. In judging the merits of alternative space missions, it is essential to keep in mind the major scientific or technological questions to be answered.

This paper attempts first to summarize the major questions men are now asking about the solar system. A priority listing of specific goals for exploration is then made taking into account both the importance of the information obtained and the likelihood of early attainment. A list of technological information needed for these goals follows, and finally, a few comments on the strategy and means of exploration are made.

General Goals

The Space Science Board of the National Academy of Sciences has recently stated (1) that the exploration of the solar system bears on three central scientific questions of our times:

I. The origin and evolution of the Earth, Sun, and planets;

II. The origin and evolution of life;

III. The dynamic processes that shape man's terrestrial environment.

A fourth major question should be added in this discussion:

IV. What are the detailed properties of the spatial environment surrounding the Sun and the planets, and what is the Sun's role in this environment?

These questions are of central importance not only in relation to the solar system but also in regard to the role of the solar system in the universe. We shall take the pursuit of answers to these four questions as our basic goals in exploration of the solar system.

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SCIENTIFIC QUESTIONS IN EACH OF THE GENERAL GOALS

Having stated these four goals, we can now break each into a set of more specific scientific questions. These will be listed in two priority groupings: most important, and important.

I. The Origin and Evolution of the Solar System

A. Most Important

1. What was the source of the material and mechanism of formation of the sun, the planets, their satellites and the asteroids?

   a. What are the chemical compositions of all these bodies, and can they have come from a common source such as the solar nebula?

   b. Was the formation of our solar system typical of processes still occurring during star formation?

   c. How are the differences in chemical composition of the "earth-like" and the "major" planets explained?

   d. Are some asteroids or meteoroids composed of primordial matter captured from outside the solar system?

2. What is the time scale of major events in our solar system?

   a. What major changes have occurred during its evolution?

   b. Can these be dated by information stored in the surfaces of the explorable bodies?

   c. What further information on the historical evolution of the system can be obtained by precise measurements of orbital characteristics and their present time rate of change?

3. What are the physical processes responsible for the principal energy release of the sun and for solar surface activity?

B. Important

1. What explains the present distribution of masses in orbit at various radii from the Sun?

2. How stable is the present solar system configuration?

3. What is the mechanism of trapping of one body by another during close passage, and what are the effects left upon the bodies?

4. What is the origin and age of matter trapped in libration regions?

5. What is the state of matter at extremely high densities and/or temperatures, as at the center of the Sun or the major planets?

II. THE ORIGIN AND EVOLUTION OF LIFE*

A. Most Important

1. What is life? Is it merely a property of highly organized matter?

2. Is there now or was there ever recognizable life elsewhere in the solar system?

3. Are there other chemical systems than that of hydrogen-carbon out of which living systems could arise?

4. What are the necessary conditions for the origin of primitive life and what is the probability of its occurrence?

B. Important

1. Could we learn more of the evolutionary process by examining life forms behind or ahead of those on earth?

2. Is the range of mutational variety much greater or less in other environments than on earth?

3. Could species exist and evolve with resistance to extreme radiation levels, and could we learn from them to develop radiation resistance in earth life systems?

*See Ref. 2

4. Could terrestrial species adapt to the environmental conditions of other planets, and vice versa?

5. What effects upon the evolution of a planetary surface environment can be expected in the complete absence of life?

III. THE DYNAMIC PROCESSES THAT SHAPE MAN'S TERRESTRIAL ENVIRONMENT

A. Most Important

1. What was the geologic evolution of the earth in terms of internal energy, differentiation, seismic processes and surface erosion?

   a. What can be learned of these by examining another earth-like planet in a different stage of geological evolution?

   b. Will the examination of the shape or composition of a small asteroid or satellite with no volcanic history, no atmosphere and no life, allow us to deduce its origin or teach us the roles these factors have played on earth?

2. What are the atmospheric dynamics of Mars, Venus or Jupiter, where all important parameters are vastly different from those on earth?

3. Can the seasonal changes observed on the Martian surface, (polar cap movement and color changes), be understood in terms of terrestrial phenomena?

B. Important

1. What are the characteristics of tidal distortions of one body by another, and what role has this effect played in the evolution of planets and their motion?

2. What are the wavelengths and transparencies of the "windows" through the cloud cover of Venus, and of what are the clouds composed?

3. What explains the giant Red Spot and the Dark Bands of Jupiter?

4. What type of particles make up the rings of Saturn and what is their origin?

IV. PROPERTIES OF INTERPLANETARY SPACE AND THE INTERACTION OF THE SUN WITH THE PLANETS

A. Most Important

1. What is the mechanism responsible for generating the solar wind?

2. What are the overall effects of the solar wind throughout and beyond the solar system?

   a. How does it shape the magnetosphere around planets with magnetic fields, or interact with others having no magnetic field?

   b. Is it the energy source for particles in trapped radiation belts?

   c. How far does it extend beyond the earth and does it terminate abruptly?

3. Which planets beside Earth and Jupiter possess magnetic fields and trapped radiation belts?

4. What are the source, composition and orbital characteristics of micrometeoroids and the heliocentric dust particles giving rise to the zodiacal light?

B. Important

1. Do trapped radiation belts outside the solar system give rise to the very high energies of galactic cosmic rays?

2. Will we find that as we leave the noise source of the earth, enormous amounts of information reach into the solar system from outer space, (at low signal levels) in the form of gamma rays, x-rays and long radio waves?

3. What is the distribution and extent of the hydrogen cloud trapped about the Sun and the earth?

4. How does the particle flux from the Sun create the earth's auroras and contribute to upper atmosphere heating?

Specific Goals for Exploration in the Solar System

We now write down a list of specific objects in the solar system to be explored. This exploration should provide many answers to the above scientific questions. We place them in a rough priority that reflects a general consensus of opinion (1) and is based on two considerations: (1) The importance of the results that could be obtained, and (2) The likelihood on early attainment.* All our exploration relates, of course, directly to an understanding of the earth. The earth is not listed here because its primary importance is assumed.

1. The Sun and its radiations
2. } Mars, Venus
3. }
4. The Moon
5. Major Planets
6. Comets and Asteroids
7. Mercury
8. Pluto
9. Dust

It is easily seen that exploration of each of these objectives will yield answers to several or all of the four general goals listed above. The sun as the center of our system, the source of our energy and possibly the source of the matter for all the planets, represents a primary goal of exploration from which many other answers should result. The detailed rationale for the priority of the remaining goals has been given in Refs. 1 & 3. The exploration of the environment between sun and planets, general goal (IV), will proceed naturally from experiments connected with all other objectives in this list.

Need for Technological Data

While a complete answer to all the scientific questions above would also supply the need for technological data for the design of spacecraft hardware for specific missions, we are not likely to get these answers soon and in detail. Hence it is wise to itemize the more specific "hard number" answers we shall need early concerning each body where we wish to orbit or land probes or men. These can be summarized as follows:

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*This list is identical to that given in Ref. 1, with two exceptions: The Space Science Board has since placed more emphasis upon Venus than the Moon, and the Sun is included here since the entire solar system, not just planetary exploration, is involved.

1. Pressure, temperature and composition profiles of the atmosphere. (This means Mars and Venus as soon as possible).

2. Surface topography, bearing strength and photometric properties.

3. Planets' optical figure and gravitational field.

4. Surface temperature, cloud habits, wind velocities, dust storms, precipitation and other climatic data.

5. Meteoritic and radiation flux at the surface.

Means and Strategy in Exploration

Only a few general remarks on this subject are appropriate here.

It seems clear that a national (or international) program designed to pursue the broad goals of the exploration of the solar system, should make use of the entire spectrum of experimental approaches available. These can be listed briefly, in order of increasing expense and complexity, as

1. Earth-based observation.

2. Rocket, balloon or earth orbital observation (unmanned).

3. Unmanned probes to the planets or around the sun with dropped probes or orbiters.

4. Manned earth-orbital observation

5. Manned flybys with dropped probes and orbiters.

6. Manned planetary orbital missions.

7. Manned landings.

8. Extended manned exploration.

A reasonable program must be sure to support the early, simple approaches as long as they are able to yield significant data that will assist more complex missions. Thus, for example strong support for ground based and earth orbital telescopic studies of the atmosphere of Mars and Venus are clearly needed now, but are not being proposed or funded with sufficient emphasis. Again, the surface and atmospheric temperature of

Venus is a crucial question upon which all future exploration plans for Venus depend: yet there are no definite plans for an early, simple, unmanned drop-sonde into the Venus atmosphere that could easily supply these data.

A final point in planning mission strategy: adequate time must be allowed between two successive explorations of the same planet so that experiments carried on the second mission can take advantage of information gained on the first.

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Attachment
Bibliography

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BIBLIOGRAPHY

1. Space Research, Directions for the Future, Part One, Space Science Board, National Academy of Sciences, National Research Council, Woods Hole Study, 1965.

2. Biology and the Exploration of Mars: Space Science Board, Natural Academy of Sciences, National Research Council, Washington, D.C., 1966.

3. Priorities in Planetary Exploration, G.J.F. MacDonald, Astronautics and Aeronautics 4, 34, 1966 (June).